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REPORT ON INSECTICIDES IN LAKE MICHIGAN

Lake Michigan Enforcement Conference.
Lake Michigan Interstate Pesticides Committee

November 1968

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REPORT ON INSECTICIDES IN LAKE MICHIGAN

Prepared by Pesticides Committee

of

The Lake Michigan Enforcement Conference

November 1968

UNITED STATES
DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
GREAT LAKES REGION
33 EAST CONGRESS PARKWAY, ROOM 410
CHICAGO, ILLINOIS 60605

INTRODUCTION

One of the sixteen conclusions reached by conferees of The Four State Enforcement Conference on pollution of Lake Michigan (January-March 1968) is:

> "Pesticides are found in Lake Michigan and its tributary streams resulting from the application of these materials. The ever-increasing use of these materials threatens water uses for recreation, fish and wildlife, and water supplies."

The conferees took positive action toward review and study of the pesticide problem in Lake Michigan in their recommendation No. 15:

> "A technical committee on pesticides will be established to be chaired by a member of the Federal Water Pollution Control Administration with representatives from each state. The committee shall evaluate the pesticide problem and recommend to the conferees a program of monitoring and control. The first report will be submitted in six months to the conferees. The states shall seek legislation to license commercial applicators."

Accordingly, the pesticide committee members were appointed, and held meetings in Chicago, Illinois on May 17, June 11-12, and July 9-10, 1968 and in Duluth, Minnesota on September 19-20, 1968. The committee consists of:

Dr. Donald I. Mount, Federal Water Pollution Control Administration, Chairman

Mr. Benn J. Leland, Illinois Sanitary Water Board

Mr. Stephan Kin, Indiana Water And Waste Laboratory

Mr. John Favinger, Indiana Natural Resources Department

Mr. Carlos Fetterolf, Michigan Water Resources Commission

Mr. Lloyd Lueschow, Wisconsin Department of Natural Resources

Mr. John Carr, Bureau of Commercial Fisheries

Dr. Oliver B. Cope, Bureau of Sport Fisheries and Wildlife

The following report of the technical committee on pesticides contains recommendations based on information obtained by the committee from published material, testimony of experts, unpublished data from studies not yet completed, and from the background and experience of the committee members. Despite this wide range of sources, the information was scanty on most aspects of pesticides in the Lake Michigan watershed, and totally lacking in several critical areas. These factors had a pronounced effect on the nature and scope of the committee's recommendations.

Despite considerable effort by the committee, information necessary to determine the quantity and kinds of pesticides in Lake Michigan was not obtainable, and apparently such information would require large expenditures of time and money. The committee recognized a pressing need for a system to obtain such information. The only significant information available was the levels of DDT and dieldrin (both insecticides) present in Lake Michigan fish.

This report includes only insecticides since there is no information to suggest that any significant amount of pesticide, other than insecticides, has been detected in Lake Michigan or its aquatic organisms. Thus, the word insecticide is used henceforth.

PROBLEMS RESULTING FROM INSECTICIDE ACCUMULATIONS IN LAKE MICHIGAN

Several indications of insecticide hazards in Lake Michigan have been reported, some of them based on insecticide measurements in the basin and some based on situations in other parts of the country and recognized as probable eventualities in Lake Michigan. The more important ones follow.

Pesticides in Lake Michigan Water

Water samples from Lake Michigan contain insecticides. Samples collected in July 1968 at points five miles west of Ludington, Michigan, and twenty-five miles west of Saugatuck, Michigan, contained chlorinated hydrocarbons. The collections were extracted, and aliquots of the extract were consigned to the Bureau of Commercial Fisheries Laboratory at Ann Arbor, Michigan; Wisconsin Department of Agriculture Laboratory at Madison, Wisconsin; and the Fish-Pesticide Research Laboratory, Columbia, Missouri. The analytical results from these three laboratories were in close agreement, showing the Saugatuck sample to contain approximately .002 µg/l of DDT, less than .001 µg/l of DDD (TDE), a trace of DDE, and approximately .001 µg/l of dieldrin. The sample from Ludington contained slightly

greater quantities of DDT and dieldrin and about the same quantities of DDD and DDE. (Note that .001 µg/l [one part per trillion] of DDT = 167,000,000,000 molecules per liter.) These samples should be representative of Lake Michigan's open water areas, and the amounts of insecticides indicative of widespread distribution throughout the greater portion of the lake. Insecticides are also found in tributary streams which are likely the principal source supplying Lake Michigan.

Hazards to Fish Reproduction

The Michigan Conservation Department has found DDT to be the most probable cause of death of nearly one million coho salmon (Oncorhynchus kisutch) fry hatched from Lake Michigan brood stock. New York studies have established that insecticide accumulations in lake trout (Salvelinus namaycush) brood stock result in reproductive failure. In light of the New York studies and the current residue of DDT and dieldrin in Lake Michigan fish, it is likely that natural reproduction of lake trout and coho salmon in Lake Michigan is in jeopardy. Other fish species in Lake Michigan probably face similar reproductive hazards although

there is evidence only for these two species. Other important commercial and sport fishery species known to have significant insecticide residues include chubs (Leucichthys spp.), alewives (Pomolobus pseudo-harengus), yellow perch (Perca flavescens), and smelt (Osmerus mordax). All are important in the bionomics of the lake.

Hazards to Bird Reproduction

Wisconsin workers have suggested an insecticide-induced reproductive hazard to gulls in the Green Bay area. This does not imply that the gull population in the Great Lakes area is declining, but suggests a possibility of failures in desirable bird populations. Indeed, the diminishing population trends of raptorial birds, such as eagles, osprey and peregrine falcons in the Lake Michigan drainage basin have been attributed to widespread use of DDT and other insecticides.

Hazards to Human Health

The United States Food and Drug Administration has established no tolerance level of insecticides in fish utilized for human consumption. The presence of residues in fish flesh has been established by Wisconsin, Michigan,

and Federal investigators. The Bureau of Commercial Fisheries has analyzed approximately 30 species of Great Lakes fish in the last three years and has observed insecticides in all species collected from Lake Michigan. The concentration of DDT in chubs from Lake Michigan has averaged 7.5 µg/g plus analogs. Other species have lower but significant quantities of DDT; dieldrin was found in all fish analyzed. The concentration of residue in Lake Michigan fish is usually two to five times higher than in other Great Lakes fish and is substantially higher in fish from smaller Wisconsin lakes.

Although the presence of residues in Lake Michigan fish has been established, the effects of these residues on human health have not been evaluated. The letter of June 4, 1968 (attached) from R. E. Duggan, Food and Drug Administration, states that the FDA has "no petitions for tolerance in fish" and has no "plans to establish tolerances on the initiative of the Commissioner." They further state, "We are not in a position to comment on the effects of pesticide contamination of Lake Michigan on human health," and after considering analytical and technological problems, ".... we concluded that legal action is warranted when 0.3 ppm aldrin, dieldrin, endrin, heptachlor or heptachlor

epoxide, is present in the edible portions of fish." The Ann Arbor Laboratory (Bureau of Commercial Fisheries) has found some fish with 0.3 ppm dieldrin total body concentrations.

Reproductive Failure of Mink Fed on Lake Michigan Fish

The Research Advisory Committee of the Mink Ranchers Association has suggested that mink fed on Lake Michigan fish having a high DDT level have failed to reproduce. The Association has initiated research contracts to determine if there is a correlation between pesticide levels in the mink food and the observed reproductive failures.

Relation of Insecticides to Other Pollutants

Evidence of numerous pollutants in Lake Michigan is well documented. Wastes from municipalities, industries, agriculture, and watercraft have contributed to eutrophication, bacterial contamination, excessive algae populations, local oxygen depletions, heated water, and other nuisances. The effects of this complex pollution may be magnified by insecticide pollution either directly or indirectly. Insecticides may not be toxic in the observed concentrations themselves, but as part of a complex of stresses placed on

organisms, they may be much more damaging.

The Committee views the quantities of insecticides in Lake Michigan as an immediate problem affecting aquatic life but not human health. It is essential that public officials, industry, and the community recognize this problem and take the necessary action to alleviate hazards caused by insecticide contamination. The higher concentration of insecticides in Lake Michigan fishes, as compared to fishes of the other Great Lakes, suggests that with proper control, lower concentrations can be achieved in Lake Michigan.

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
FOOD AND DRUG ADMINISTRATION
WASHINGTON, D.C. 20204

June 4, 1968

Dr. Donald I. Mount
Chairman, Pesticides Committee
Lake Michigan Enforcement Conference
Federal Water Pollution Control Administration
U. S. Department of Interior
6201 Congdon Boulevard
Duluth, Minnesota 55804

Dear Dr. Mount:

Your letter of May 23 requests information on pesticide residue problems associated with Lake Michigan. We are not in a position to comment on the effects of pesticide contamination of Lake Michigan on human health. There have been instances where the pesticide residue content of fish caught by commercial fishermen in Lake Michigan have been substantial and consideration was given to appropriate legal action. Tolerances for pesticide residues as such, or as food additives, in fish could be established under Section 408 or 409 of the Food, Drug and Cosmetic Act. No petitions for tolerances in fish have been submitted, nor do we have plans to establish tolerances on the initiative of the Commissioner.

After giving due consideration to analytical problems in sampling, sensitivity and reliability attainable in routine analyses, as well as current knowledge on the toxicology of specific residues, we concluded that legal action is warranted when 0.3 ppm aldrin, dieldrin, endrin, heptachlor or heptachlor epoxide, is present in the edible portion of fish. This guideline will be reevaluated and changed as additional information becomes available and is not to be construed as a tolerance.

The above figures are applicable only where there is no history of purposeful use of the pesticide which would result in residues in fish. Furthermore, we would not consider these levels acceptable if a significant proportion of fish marketed contained this concentration of residue.

In addition to the problem of residues in fish for human consumption, attention should be given to the use of fishery products in animal feeds which might result in residues in meat, milk and eggs.

We are referring your letter and a copy of our reply to the Federal Committee on Pest Control for their information. You may wish to seek suggestions from that Committee, if you have not already done so.

If we can be of further assistance or provide additional information on specific questions, we will be glad to do so.

Sincerely yours,

R. E. Duggan
Deputy Associate Commissioner
for Compliance

INSECTICIDE USE

The kinds and quantities of insecticides used in the past, those being used now, and those predicted for the future bear directly on the presence and distribution of insecticides in Lake Michigan and on steps to be recommended to decrease the amounts in the lake and its biota. The Committee has exerted effort to compile information on types, amounts, and distribution of insecticides applied in the Lake Michigan drainage basin, and has learned that there are no accurate, consistent compilations of such information. Fragmentary figures are available for some areas and for some insecticides, but extrapolation of these numbers into realistic totals for the drainage basin appears impossible at the present time. Even the following general statements on usage are subject to great error; the values are only general indications and should be used cautiously.

Approximately 1.25 million acres of Indiana land drains into Lake Michigan. Much of this area is heavily industrialized and urbanized and the remainder is devoted to dairy and general farming. About 58,000 acres of Illinois is in the Lake Michigan watershed; most of this area is highly-developed industrial and residential area.

The Lake Michigan drainage area in Wisconsin measures about 250 miles long, and up to about 150 miles wide; this area has extensive orchard and other farm acreage, as well as forests. Michigan lands in the drainage basin are extensive, and include approximately one-half of the entire state (approximately 29,100 square miles). In this area are vast forests, numerous Christmas tree farms, and widespread agricultural lands, including the greater part of the Michigan fruit belt.

In 1964 approximately 3.8 million pounds of insecticides were used on crops in the three lake states of Minnesota, Michigan, and Wisconsin (U.S.D.A., 1968). It is not known what portion of this was applied in the Lake Michigan watershed. In the lake states the greatest amounts of the insecticides were used on apples and other deciduous fruits. Aldrin (that converts to dieldrin) used on the largest acreage on corn, totaled 761,000 pounds on approximately 1.2 million acres. DDT was applied to about 150,000 acres and accounted for 511,000 pounds.

The State of Wisconsin estimates that in its segment of the Lake Michigan drainage basin approximately 150,000 acres of farm lands received 500,000 pounds of technical

insecticides in 1967. Of this, 86,600 pounds was DDT, 4,200 pounds was dieldrin, 103,800 pounds was chlordane, and 28,000 pounds was toxaphene. Most of the remainder was composed of non-persistent insecticides.

Based on 1966 insecticide application data and 1964 crop average data, the agricultural use of persistent chlorinated hydrocarbons, in the Michigan portion of the drainage basin is considerably less than the fungicides, phosphates and herbicides. Of the persistent materials, aldrin, DDT, and dieldrin were the most frequently applied and were used primarily on grain crops and fruits. Dieldrin and DDT were applied in much greater amounts before 1966.

The Lake Michigan drainage basin is not typical of the rest of the United States in respect to the distribution of insecticide use. In the corn belt and cotton belt states there is a much higher percentage of insecticide use on field crops, while the basin use is perhaps 60% metropolitan and 40% agricultural. Throughout the greater part of the Lake Michigan drainage basin municipalities have made heavy use of DDT for control of the lesser European elm bark beetle, the principal vector of Dutch elm disease. The amount of DDT applied to a large elm tree approximates that

normally applied per acre for field crop purposes. DDT spraying is largely municipally-sponsored and trees in parks and along streets are sprayed mainly in the spring. Considerable insecticide drops to paved areas and is washed away by storm water directly into tributaries of Lake Michigan. Mosquito abatement programs are also common in the resort and residential areas in much of the basin. Persistent insecticides applied for the above purposes have less opportunity to become bonded to soil particles than do those applied directly to crop areas for insect control.

The Lake Michigan drainage area must have received immense amounts of pesticides in recent years. Prospective future use, based on present trends, suggests increased emphasis on the less persistent insecticides and decreasing reliance on the persistent chlorinated hydrocarbons.

MONITORING PROGRAMS

It is axiomatic that a program of insecticide measurements in the Lake Michigan environment would have helped us recognize the existence of an insecticide problem, but a monitoring program will be indispensable in following future changes, whether or not a control program is implemented.

Some measurements of insecticides in this ecosystem have been made in recent years. Certain of these programs could be classed as monitoring activities, but data have also been accumulated from individual studies restricted as to times and places. All of these have added to our knowledge and helped form our impressions of the history of insecticides in the water and the animals of Lake Michigan.

During the past three years the Ann Arbor Biological Laboratory of the Bureau of Commercial Fisheries has been measuring insecticide levels in fish from each of the Great Lakes. Some results from these studies are included in Table 1. The same laboratory has collected many water samples from Lake Michigan and has found DDT and dieldrin in measurable amounts.

Table 1
Pesticide Residues in Whole Fish from
Lake Michigan, 1965-1968*

Species	Number of fish	Pesticide concentration (ppm) Dieldrin	Total DDT (DDT, DDD, DDE)
Alewife	663	0.11	3.93
Chubs	384	0.24	10.11
Smelt	239	0.08	3.01
Perch	200	0.06	3.28
Lake trout			
3-5"	10	0.02	1.07
6-9"	61	0.11	2.99
10-13"	40	0.13	4.31
16-20"	19	0.21	6.64
Coho salmon			
10-22"	15	0.14	3.45
25-30"	4	0.15	12.59

* Bureau of Commercial Fisheries data

In the past few years, the Ontario Water Resources Commission has analyzed fish from Lakes Erie and Ontario and other waters.

The U.S. Department of Agriculture conducts the soil monitoring portion of the National Pesticide Monitoring Program, including the Lake Michigan watershed. Sampling began on July 1, 1968, and no results are yet available.

The Wisconsin Department of Natural Resources is studying the sources, seasonal variation, and residues in fish of chlorinated hydrocarbon insecticides, in the Milwaukee River and its tributaries. The department is also investigating insecticide residues in invertebrate organisms in streams tributary to Lake Michigan.

At the Michigan State University, studies are in progress on the effects of insecticides on populations of salmonids in Lake Michigan, on the nature and metabolic activity of lipids associated with insecticides residues in fish eggs, and on environmental and physiological factors affecting the toxicity of accumulated insecticide residues.

The literature contains recent reports on insecticides in the Lake Michigan drainage, including the Green Bay area. Reports have also been published on herring gull reproduction,

occurrence of insecticides in the Lake Michigan ecosystem, and DDT and dieldrin levels in Great Lakes fish. No known programs exist that will indicate the contribution of airborne insecticides to the lake.

RECOMMENDED MONITORING PROGRAM

A monitoring program would provide up-to-date information on the pesticide contamination within the aquatic ecosystem of Lake Michigan and its drainage basin. Such information would be used in the management and protection of the water resources and specifically for the protection of sport and commercial fish.

To stay within practical limits of time, money, and manpower, the Committee recommends a four-point approach to the monitoring program: changes in insecticide levels should be measured in 1) major tributaries; 2) minor tributaries; 3) Lake Michigan water; and 4) fish of Lake Michigan.

Monitoring

To be of greatest value, the monitoring program must include those insecticides of currently acknowledged significance to human health and to growth and reproduction of aquatic life. It must measure quantities at reproducible levels to establish current concentrations and to trace future trends. The Committee has selected seven contaminants (Table 2) and their levels of detection for routine analysis

Table 2

Insecticides and the Lower Values of Quantitative Reporting Recommended for Various Types of Monitoring.

Insecticide and priority order of analysis	Tributary water µg/l	Lake water µg/l	Fish tissue µg/g	Clam tissue µg/g
DDT	.020	.001	0.1	0.1
Dieldrin	.020	.001	0.1	0.1
DDD	.020	.001	0.1	0.1
DDE	.020	.001	0.1	0.1
Methoxychlor*	----	----	0.1	0.1
Chlordane*	----	----	0.1	0.1
Endrin	----	----	0.01	0.1

* If detected in fish tissue at concentrations greater than 0.1 µg/g, quantitative reporting should be changed to a 0.01 µg/g limit.

by gas chromatograph, to provide the information necessary to meet the objectives.

Major Tributaries Recommnded for Sampling

The Committee recommends nine major tributaries of Lake Michigan to be sampled continuously for three days (Table 3), once each month. The purpose is to determine the poundage of insecticides supplied by the major tributaries to Lake Michigan. Sampling stations should be located as close to the lake as practical. Two stations are recommended on the Milwaukee River, one near the mouth and one above the industrial area, to differentiate between agricultural and urban contamination. Water samples for pesticides are to be analyzed without filtration; subsamples are to be analyzed for suspended solids and turbidity.

The three-day continuous sampling method is recommended to detect fluctuations in turbidity and pesticide loads. Although the sample volume will not be proportional to stream flow, it can be related to discharge rate to secure quantitative information.

The apparatus for continuous flow sampling can be a pump with a capacity to deliver about 200cc of stream water

Table 3

Recommended Water Quality Monitoring Stations
for Insecticides on Major Tributaries.

River	Proposed station location	Est. mean annual flow (cfs)	Est. mean annual high flow (cfs)	Est. mean annual low flow (cfs)	Watershed (sq.mi.)	Percentage of basin gaged
Fox*	Main St. Bridge, Green Bay, Wis.	4,154	12,983	1,207	6,150	--
Grand** Calumet	Dickey Road, East Chicago, Ind.	864			37	--
Grand	Corps of Engineers, Grand Haven, Mich.	4,000	23,820	924	5,570	88
Kalamazoo	U. S. 31 Bridge, Saugatuck, Mich.	1,722	5,812	512	2,060	78
Manistee	Maple St. Bridge, Manistee, Mich.	2,312	5,937	1,322	2,130	93
Menominee	Ogden St. Bridge, Marinette, Wis. Menominee, Mich.	3,382	15,150	994	4,070	93
Milwaukee ***	Machinery Bay, Milwaukee	385	4,640	28	686	--
Milwaukee	Above urban area	Currently unavailable				
Muskegon	Coast Guard, Muskegon, Mich.	2,176	7,750	698	2,660	88
St. Joseph	Ches. & Ohio RR Bridge St. Joseph, Mich.	2,312	5,937	1,322	2,130	93

* Data from Wrightstown, Wis.
** Data from Gary, Ind. stage-flow relationship plus industrial and municipal discharges.
*** Data from six miles above mouth.

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per hour into a 5-gallon covered bottle. Larger pumps can be used if a bleeder is provided to deliver the indicated amount. (Suitable pumps are commercially available for approximately $50 each.) The water should be drawn through metal tubing from a section of stream with a visible current.

Studies at Michigan State University have demonstrated that the majority of phosphorus is carried by a stream during relatively few days of each yea-. Insecticides are likely to behave similarly and, because data on the total tributary contribution are desired, grab samples are not adequate.

Biological Sampling of Tributaries

The Committee recommends a one-year program of biological monitoring in most tributaries during the ice-free season (Table 4). The main purpose of the monitoring is to identify sources of insecticides from tributaries other than the nine named in the major tributary water sampling program. Living clams will be used to sample water.

Clams siphon and filter large volumes of water and concentrate insecticides to levels many times greater than that of the water. Insecticide levels found in clams reflect concentrations which existed in the water two to three weeks

TABLE 4

Tributary Streams Recommended
for Biological Monitoring

Tributary	Location
Michigan	
Galien River	LaPort Road, New Buffalo, Michigan
Drain	Sawyer, Michigan
St. Joseph River*	U.S. 31 Bridge, St. Joseph, Michigan
Paw Paw River	Above St. Joseph, Michigan
Black River	U.S. 31 Bridge, South Haven, Michigan
Kalamazoo River*	U.S. 31 Bridge, Saugatuck, Michigan
Black River	Ottawa Beach, Michigan
Pigeon River	Lake Shore Ave., Port Sheldon, Mich.
Grand River*	Corps of Engineers, Grand Haven, Mich.
Muskegon River*	Coast Guard, Muskegon, Michigan
White River	S. Channel wall, Whitehall, Michigan
Pentwater River	Coast Guard, Pentwater, Michigan
Pere Marquette River	Channel area, Ludington, Michigan
Manistee River*	Maple St. Bridge, Manistee, Michigan
Betsie River	Coast Guard, Frankfort, Michigan
Platte River	M-22, Benzie State Park, Michigan

* Water monitoring station for pesticide analysis.

Table 4 cont'd.

(Michigan)	
Crystal River	Bay Lane, Glen Arbor, Michigan
Leelanau Lake outlet	Leland, Michigan
Boardman River	Traverse City, Michigan
Elk River	Elk Rapids, Michigan
Lake Charlevoix outlet	Charlevoix, Michigan
Bear River	Petoskey, Michigan
Millecoquins Creek	Naubinway, Michigan
Manistique River	Manistique, Michigan
Sturgeon River	Nahma, Michigan
Whitefish River	U.S. Bridge, Rapid River, Michigan
Escanaba River	Wells, Michigan
Ford River	M-35 Bridge, Ford River, Michigan
Menominee River*	Breakwater, Menominee, Michigan
Indiana	
Grand Calumet River*	East Chicago, Indiana
Burns Ditch	Midwest Steel Catwalk, Burn Harbor, Indiana
Trail Creek	Franklin St. Bridge, Michigan City, Indiana

* Water monitoring station for pesticide analysis.

Table 4 cont'd.

Wisconsin

Peshtigo River	Marinette County
Oconto River	Oconto County
Pensaukee River	Oconto County
Little Suamico River	Oconto County
East River	Brown County
Suamico River	Brown County
Mink River	Door County
Unnamed Streams (7)	Door County
Ahnapee River	Kewaunee County
Kewaunee River	Kewaunee County
East Twin River	Manitowoc County
West Twin River	Manitowoc County
Manitowoc River	Manitowoc County
Silver Creek	Manitowoc County
Calvin Creek	Manitowoc County
Pine Creek	Manitowoc County
Point Creek	Manitowoc County
Fisher Creek	Manitowoc County
Centerville Creek	Manitowoc County
Seven Mile Creek	Sheboygan County
Pigeon River	Sheboygan County

Table 4 cont'd.

(Wisconsin)

Sheboygan River	Sheboygan County
Black Creek	Sheboygan County
Sauk Creek	Ozaukee County
Menomonie River	Milwaukee County
Kinnickinnic River	Milwaukee County
Oak Creek	Milwaukee County
Root Creek	Racine County
Pike River	Kenosha County
Barnes Creek	Kenosha County

before the sampling time.

Only high insecticide concentrations are of interest on the smaller streams; lower concentrations would not contribute significantly to the total concentration in the lake.

This program should begin in early spring before the insecticide spraying season, and extend into the fall. Clams should be placed in wire baskets suspended a short distance above the stream bottom. The concentration of insecticide in the clams will reach equilibrium in two to three weeks. If exposure ceases, accumulations are lost in approximately the same period. Sufficient numbers of clams should be used so that sub-samples of three each can be removed every four to six weeks and at times such as following heavy runoff during peak insecticide application periods.

The single composite sample of three clams may be placed in formalin or frozen before analysis. Lampsilis siliquoidea, a widely distributed clam found in moving and still water, is the most desirable species. Fusconaia is also suitable, but because concentration rates may vary among species, the same species should be used for all sampling.

The presence of the crystalline style in the esophagus of the clam indicates feeding activity and that the animal has been filtering normally, accumulating extant insecticides. The examination for this structure is rapid and simple and will provide useful information.

Lake Water Sampling

The Committee recommends two sampling areas be established in the central portion of the lake, one in the northern basin and one in the southern basin. Three samples of surface water should be collected three times each year at each station. Horizontal and vertical distribution of insecticide concentrations are not justified for inclusion in this monitoring program since meaningful values would require large numbers of samples and the data would be difficult to interpret.

It is recommended that the water intake of the Chicago Central District Filtration Plant be sampled weekly for insecticide analysis. Information furnished by FWPCA's Great Lakes-Illinois River Basin Project indicates that this intake water is representative of open lake water on most days of the year. Unusual weather conditions and wastes and storm runoff entering the lake may alter the

quality of this intake water but such effects will be apparent in the routine water quality analyses. The principal purpose of this sampling point is to provide a source of reproducible samples to furnish data on long-term trends. Such information is necessary to evaluate the effectiveness of the insecticide control program.

Fish Sampling

Fish accumulate insecticides to concentrations many times the levels of their surroundings. Analyses of tissue from Lake Michigan fish by Federal and State agencies indicate insecticide levels approaching limits currently suggested by the U.S. Food and Drug Administration. The levels are three to five times higher than those in the same species of fish from the other Great Lakes.

The Committee recommends that four species of fish be collected in April and October at four sampling stations on Lake Michigan. Two samples of 10 fish (5 of each sex) are to be examined in accordance with the schedule in Table 5.

TABLE 5

Recommended Insecticide Analysis for Fish
to be Collected in April and October

Station*	Species	Number of Samples	Composition of samples
Green Bay	Alewives	2	5 males, whole body
		2	5 females, whole body
	Yellow perch	2	5 males, muscle only
		2	5 females, muscle only
Waukegan, Saugatuck, and Charlevoix	Alewives	2	5 males, whole body
		2	5 females, whole body
	Yellow perch	2	5 males, muscle only
		2	5 females, muscle only
	Chubs	2	5 males, muscle only
		2	5 males, whole body
		2	5 females, muscle only
		2	5 females, whole body
	Coho salmon	2	5 males, muscle only
		2	5 females, muscle only

*Station choice based on location of commercial fisherman and not requiring special collecting.

Assignment of Insecticide Analyses

The Committee has been advised that the City of Chicago will undertake routine insecticide analyses on Lake Michigan water withdrawn at their intake. We therefore recommend that the city be requested to perform analyses for insecticides on open water and intake water samples in accordance with the schedules described above.

The U.S. Department of the Interior, Bureau of Commercial Fisheries' Biological Laboratory in Ann Arbor, Michigan is already measuring insecticide levels in Great Lakes fish, especially those from Lake Michigan. The Committee recommends that this laboratory assume responsibility for collecting and analytical work on the Lake Michigan fish monitoring program. The Committee recommends that Indiana tributary water and clam samples be analyzed by the cooperating laboratory nearest to the sampling site.

Since several laboratories are likely to be involved, a rigid system of quality control is mandatory for comparable data.

Quality Control

Positive identification of all chlorinated hydrocarbons detected, as well as reproducibility and accuracy of the procedure, is of greatest importance. Therefore, the following recommendations are made to assure a reliable quality control program for water, clam, and fish samples analyzed during the survey: water samples will be analyzed by the Provisional FWPCA Interim Official Method for Chlorinated Hydrocarbon Pesticides in Water and Wastewater by Gas Chromatography, May, 1968. Additionally, a blank with the applicable volume of distilled water, as stated in the procedure, and an actual sample to check percentage recovery of an added mixture of pesticides found in the samples must be determined. One blank and one fortified sample should be interspersed with each nine field samples.

To assist the analyst in identification of suspected pesticides, two separate gas chromatography columns, with different retention times, should be employed to check relative retention time of pesticides in the samples. Further, infrared spectrometry should be employed on 5% of the water samples to confirm the routine analyses. If individual samples do not have sufficient concentration to

make infrared measurements, the residues from several samples should be composited, or carbon filters should be used, to secure sufficient quantities of insecticide for positive identification.

Fish and clams will be analyzed by the procedure as outlined in the U.S. Food and Drug Administration's Pesticide Analytical Manual, Volumes I and II, Revised January 1968. A reagent and procedure blank, using the method and number as outlined above for water, must be employed. Similarly, the pesticides used in the recovery must be a mixture of those expected to be found in the test organism and at concentrations comparable to the actual samples. Tissue samples of fish from each sampling location must be verified by positive identification of pesticides at least once each year at each location.

Data will be reported in µg/l for water samples and µg/g (wet weight) for the fish and clams.

Research Needs

Although there is ample evidence that insecticides are a hazard in Lake Michigan, the means of determining the exact detrimental effects, the levels and kinds of

insecticides, their distribution in the Lake Michigan environment, and the way in which they enter the lake are not sufficiently known. The Committee strongly recommends that research be immediately initiated to provide the knowledge needed to control pesticides realistically at levels not detrimental to the water uses of Lake Michigan. The specific research needs listed below will provide knowledge needed immediately on the Lake Michigan watershed to control the use of insecticides effectively and to determine what remedial actions are necessary. The Committee realizes that no one agency is capable of conducting all of the needed research and is not, therefore, attempting to recommend who shall do the work.

The significance of research on the following specific problems is vital to evaluation of the effect of insecticides in the Lake Michigan watershed:

1. <u>The effect of insecticide residues in the fish's body, on fish growth and reproduction</u>. Although considerable evidence has been advanced to show that insecticide levels in coho salmon, for example, have affected their reproduction, we do not know the levels that would have no effect in this species. There is increasing

evidence that a residue value that is detrimental in one body of water may not be harmful in another aquatic habitat. The research, therefore, must be done on Lake Michigan.

2. The mechanism of insecticide transport into and within the lake. At the present time almost nothing is known about transport of insecticides into Lake Michigan. Results of the monitoring program will partially answer this question, but detailed studies are needed to determine the percentage of insecticides entering from streams (both dissolved in the water and sorbed on suspended material) and directly to the lake from the atmosphere (rain or wind-carried spray).

3. The effect of bound insecticides (not in solution) on fish. Apparently significant amounts of insecticides reach the lake sorbed to solid particles. Whether they have an effect on fish or are simply lost to the bottom sediments must be known.

4. History of insecticide uses, including amounts and kinds in the Lake Michigan watershed. An effective control program must be based on a knowledge of past history and current status of uses.

5. The persistence of insecticides in the Lake Michigan ecosystem. Knowledge must be gained concerning the time required for the breakdown of toxic insecticides into relatively nontoxic or biologically inactive compounds. This knowledge is necessary to predict the effectiveness of any control program.

6. The effects on terrestrial organisms of insecticides occurring in the aquatic ecosystem. This knowledge is needed to establish residue levels in fish and other aquatic organisms to ensure that there will be no adverse effect on terrestrial organisms such as fish-eating birds or mammals. This level may be more critical (i.e., lower) than that needed to protect the food organism itself.

7. Combined effects of a mixture of insecticide compounds on organisms. Since many insecticide compounds occur in Lake Michigan, it is necessary to determine the effects of combinations of known insecticide residues on organisms, in addition to the effects of single compounds.

8. Determination of the proper methods of collection, storage, and analysis of samples. This study

is essential to the monitoring program recommended by the Committee, and can be a part of that program.

The Committee recommends that immediate attention be given to these eight needs, but with full realization that new research needs will undoubtedly arise as these studies progress.

CONTROL RECOMMENDATIONS

The Lake Michigan Technical Committee on Pesticides recognizes the many and varied uses of pesticides. The Committee feels that each pesticide developed has potentially legitimate uses which warrant the developmental effort; therefore, control over usage should be established with regard to the unique needs for the product, its potential side effects, accumulation potential in the environment, and the hazard of accumulations. The Committee feels that positive action should be taken not only to prevent the accumulation of persistent pesticides, but to reduce their concentration in Lake Michigan waters:

Recommendation No. 1.

> The concentration of DDT in the fish should not exceed 1.0 µg/g; DDD should not exceed 0.5 µg/g; dieldrin should not exceed 0.1 µg/g and all other chlorinated hydrocarbon insecticides, singly or combined, should not exceed 0.1 µg/g. Limits apply to both muscle and whole body and are expressed on the basis of wet weight of tissue.

The above values for DDT and DDD are based on evidence that Lake Michigan fish apparently exceed these levels, while fish of the other Great Lakes and inland waters do not. Furthermore, it appears that in coho salmon, and

perhaps other fish, reproductive capabilities are inhibited by levels that exceed these values. The 0.1 µg/g recommendation for dieldrin is based on reducing the present level of dieldrin in Lake Michigan fish.

The Committee recognizes that other chlorinated hydrocarbons apparently are not a hazard to Lake Michigan fish at this time, but a reduction in the use of DDT and DDD will result in a shift to other insecticides. It is further recognized that other insecticides may be even less tolerable than DDT and DDD and therefore contamination levels must be established now before such problems develop. The Committee recognizes that, to achieve the recommended reduction of DDT plus analogs and dieldrin in fish, it will be necessary to reduce the concentrations of each product in Lake Michigan waters possibly to less than .001 µg/l. Limits of contamination are given for fish rather than water because the permissible concentration in the water is not known.

Recommendation No. 2.

> Each state should establish a regulatory authority to control and record type, quantity and place of insecticide use.

This regulatory authority should have the power to evaluate the benefits of particular products and their uses against the potential damages that might be inherent in their use. This regulatory body should be composed of at least one representative each from the disciplines of agriculture, conservation, water pollution, health, and administration. The regulatory body would review each known insecticide use in light of its benefits and hazards and subsequently approve or disapprove its use. It would initiate among the representative agencies the necessary monitoring information required to evaluate insecticide sources within the state jurisdiction.

The regulatory authority should also be provided with technical talent capable of reviewing and evaluating the literature that is continuously becoming available. Enforcement of this authority's rules should be clearly identified in the legislation creating the group. Enforcement of policies should be intensive and aggressive to adequately protect the environment from insecticides deemed damaging or unwarranted.

Recommendation No. 3.

A Lake Michigan Interstate Pesticides Committee should be created by the conferees to attain uniformity among the states in pesticide use controls and establish uniform pesticide concentration limits in fish, water, and other aspects of the Lake Michigan ecosystem.

The Committee would review, at least annually, the monitoring results, evaluate the effectiveness of the program, and advise the conferees on needed changes in the monitoring program. This committee, after evaluating the potential ecological hazards to Lake Michigan, reviewing the inventory of products used, and evaluating uses that contribute significant quantities of insecticides to Lake Michigan, would recommend further action to substantially reduce the insecticide hazard to Lake Michigan.

Recommendation No. 4.

The research needs listed in this report should receive priority equal to that given to the monitoring program.

Recommendation No. 5.

The monitoring program presented in this report, and modified as needed, should be implemented at the earliest possible date and continue as long as the insecticide hazard exists.

Because the insecticides dealt with in this report are persistent, improvement in lake conditions will not appear as soon as sources of contamination are controlled. Only through a continuing monitoring program can the results of the control measures be evaluated.

Prepared by:
Lake Michigan Enforcement Conference Pesticides Committee,
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